

EMPTY BACKHAUL, AN OPPORTUNITY TO AVOID FUEL EXPENDED ON THE ROAD

Study Report

Prepared for

**THE NEW YORK STATE
ENERGY RESEARCH AND DEVELOPMENT AUTHORITY**
Albany, New York

Joseph D. Tario, PE
Senior Project Manager

**THE NEW YORK STATE
DEPARTMENT OF TRANSPORTATION**

Charles Moore
Project Manager

Prepared by

CALMAR TELEMATICS LLC
Liverpool, New York

Lee Maynus, PE
and
Ross D. Sheckler
Project Manager

NYSERDA Agreement Number: 11109-1-0
Comptroller Contract Number: C012668
NYSDOT Task Assignment: C-08-31
PIN: R021.28.881

NOTICE

This report was prepared by Calmar Telematics in the course of performing work contract for and sponsored by the New York State Energy Research and Development Authority and the New York State Department of Transportation (hereafter the “Sponsors”). The opinions expressed in this report do not necessarily reflect those of the Sponsors or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, the Sponsors and the State of New York make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. The Sponsors, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

DISCLAIMER

This report was funded in part through grant(s) from the Federal Highway Administration, United States Department of Transportation, under the State Planning and Research Program, Section 505 of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the United States Department of Transportation, the Federal Highway Administration or the New York State Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or and endorsement of manufacturers.

1. Report No. C-08-31	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Empty Backhaul, an Opportunity to Avoid Fuel Expended on the Road		5. Report Date November 2009	
		6. Performing Organization Code	
7. Author(s) Ross D. Sheckler, Lee W. Maynus		8. Performing Organization Report No.	
9. Performing Organization Name and Address Calmar Telematics LLC, 620 Old Liverpool Road, Liverpool, NY 13088		10. Work Unit No.	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address NYS Department of Transportation 50 Wolf Road Albany, New York 12232		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes Project funded in part with funds from the Federal Highway Administration			
16. Abstract An effort was undertaken to determine whether or not vehicle telemetry could provide data which would indicate whether a commercial vehicle was operating under loaded or unloaded conditions. With a straightforward method for establishing the load status of a commercial vehicle it becomes possible to identify whether specific regions or routes have a higher tendency to have trucks traveling without a load. A catalog of the regions or routes which have a surplus of empty trucks offers the opportunity for load matching or brokering to utilize these trucks increasing profitability and decreasing total VMT. The study develops a methodology to determine when a vehicle is operating with a light load or no load. A summary of load status in various routes and regions is compiled for the fleets in the industry sample. Conclusions on load trends are drawn and suggested uses and follow-on activities are discussed.			
17. Key Words Trucking, telemetry, VMT	18. Distribution Statement No Restrictions		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	22. Price

ABSTRACT

Modern logistics and computerized routing algorithms have optimized the operation of commercial vehicles to the point where there is little opportunity to further increase efficiency and reduce vehicle miles traveled (VMT) for a given load. As a result, opportunities to reduce VMT in the commercial sector primarily lie in maximizing the utility of each of those miles.

An effort was undertaken to determine if vehicle telemetry could provide meaningful which would serve as an indicator that a commercial vehicle was operating under loaded or unloaded conditions. With a straightforward load status analysis it becomes possible to determine the laden status of a commercial vehicle and makes it possible to identify whether specific regions or routes have a higher tendency to have trucks traveling without a load. A catalog of the regions or routes which have a surplus of empty trucks offers the opportunity for load matching or brokering to utilize these trucks, increasing profitability and decreasing total VMT.

The study develops a methodology to determine when a vehicle is operating with a light load or no load. A summary of load status in various routes and regions is compiled for the fleets in the industry sample. Conclusions on load trends are drawn and suggested uses and follow-on activities are discussed.

ACKNOWLEDGEMENTS

Calmar Telematics would like to thank the members of New York's trucking industry for continuing to support and participate in the HIVIS truck data program.

TABLE OF CONTENTS

ABSTRACT	iii
ACKNOWLEDGEMENTS	iv
LIST OF FIGURES	vi
LIST OF TABLES	vi
SUMMARY	S-1
INTRODUCTION	1
EXPERIMENTAL DESIGN	2
Feasibility	2
Challenge	3
Other Considerations	3
INITIAL HYPOTHESIS TEST	4
Petroleum Carrier Results	5
Grocery Hauler Results	6
Discussion	7
Conclusions	7
FOLLOW-UP TESTING	8
Vehicle and Fleet Characteristics	8
Initial Analysis	9
Long-Term Analysis	9
Commodity Carried Fuel Economy Variability	14
FINDINGS	20
APPLICATION	22
CONCLUSIONS	30
RECOMMENDATIONS FOR FURTHER WORK	31

FIGURES

<u>Figure</u>	<u>Page</u>
1 One Grocery Carrier Vehicle Fuel Economy	10
2 Another Grocery Carrier Vehicle Fuel Economy	10
3 Dairy Carrier Fuel Economy Variance by Vehicle	11
4 Heavy Equipment Carrier Fuel Economy Variance by Vehicle	11
5 Grocery Carrier Fuel Economy Variance by Vehicle	12
6 General Carrier Fuel Economy Variance by Vehicle	12
7 Petroleum Carrier Fuel Economy Variance by Vehicle	13
8 Select Figure 7 Drill Down Detail	13
9 Sample Distribution of Petroleum Carrier Fuel Economy	15
10 Sample Distribution of Grocery Carrier Fuel Economy	16
11 Population Distribution of For Hire Carrier Fuel Economy	16
12 Sample Distribution of Dairy Products Carrier Fuel Economy	17
13 Sample Distribution of Dairy Products Carrier Fuel Economy	17
14 Probable Empty Grocery Carrier Trips	18
15 Probable Empty For-Hire Carrier Trips	18
16 Probable Empty Dairy Products Carrier Trips	19
17 Probable Empty Heavy Equipment Carrier Trips	19
18 Probable Empty Heavy Equipment Carrier Trips	20
19 Routes with Empty Trips and Their Significance	24
20 Routes with Empty Grocery Trips	25
21 Routes with Empty Petroleum Products Trips	26
22 Routes with Empty For Hire Carrier Trips	27
23 Routes with Empty Heavy Equipment Carrier Trips	28
24 Routes with Empty Dairy Products Trips	29

TABLES

<u>Table</u>	<u>Page</u>
1 Petroleum Carrier Empty/Full Estimation	5
2 Grocery Carrier Empty/Full Estimation	6
3 Fleet and Trip Characteristics	8
4 Fuel Economy (MPG) By Carrier Type	14
5 Miles Traveled, Loaded vs. Unloaded	22

SUMMARY

The Federal Highway Administration (FHWA) has recorded a 40% increase in vehicular traffic over the last decade while the highway infrastructure has grown by less than 5% in the same time period. With a rapidly growing population and economy we have to expect that the increase in the flow of products over our highways will continue to surpass the growth in our highways.

The freight industry has adopted a number of efficiency measures including the implementation of software that generates shortest, fastest, or cheapest routes. As a result it can generally be said that truckload freight is operating at, or near, the minimum possible vehicle miles traveled (VMT) to a destination. However, trucking is a largely fractured industry with thousands of firms each focused on the task at hand, and as a result, the highly efficient, minimum VMT trip is all too frequently followed by a empty trip home. The net effect is that the trucking industry itself estimates that well over 20% of the vehicle miles traveled by commercial vehicles moves no freight.

Through a solid working relationship with the members of the New York State Motor Truck Association (NYSMTA), Calmar Telematics has held discussions with members of the NYSMTA on the value of understanding empty backhauls, what segments of the industry are prone to empty runs, and which regions have a mismatch between trucks and loads. It is the opinion of Calmar that more complete knowledge of the nature and causes of empty backhauls may allow both the trucking industry and public planners to react to help reduce the empty VMT's.

The proposed project is a Research and Feasibility study into the prevalence and distribution of empty truck trips in New York State and the northeast in general. Through the New York State Energy Research and Development Authority (NYSERDA)/NYSDOT/FHWA/Calmar effort to build the HIVIS commercial vehicle activity database Calmar has access to a significant amount of drive train data overlaid upon route structures. The dissemination of the HIVIS data allows study of trends in trip fuel economy which is directly linked to drive-train workload and therefore payload weight.

The project developed and tested rules for determining whether or not a truck is carrying a moderately heavy or heavy load. The team used the ability to determine load status to catalog regional shifts in load condition as well as trends based on the industry that is served by participating fleets.

INTRODUCTION

Commercial vehicles comprise approximately 15 % of the U.S. automotive fleet. Their activity is integral to the U.S. economy, carrying approximately 60% of goods moved within the country. Annually, commercial vehicles are estimated to travel 1.7 billion vehicle miles and consume 9.1 billion gallons of diesel fuel. Within the transportation community, it is known that a significant portion of the in-motion vehicles are empty or traveling with less than a truck load.

The basic proposition set forth in this effort is that if detailed knowledge of routes that tend to have a large percentage of empty or less than fully loaded vehicles is known, this knowledge may permit the transportation industry to find solutions to match these vehicles with revenue producing loads. If as little as 5% of the trips that are currently running empty are matched with loads, the nation could save more than 25 million gallons of diesel fuel and remove as many as 100,000 non-revenue producing trucks from the road.

Regardless, goods produced to meet market demand will be moved, since underlying economic activity warrants these goods to be carried. Calmar's data shows that the average heavily laden truck will get 4.0 miles per gallon and an unloaded or lightly loaded truck may get as much as 6 miles per gallon. Using these fuel economy averages, goods carried 250 miles will use 62.5 gallons of fuel to make the delivery. If the truck returns to its origin empty, then additional 41.7 gallons of fuel is consumed, resulting over 104 gallons of fuel being consumed to deliver the goods.

On the other hand, a fully loaded returning vehicle will consume about 62.5 gallons. However, that fuel consumed is coupled with a separate load that would have been moved in any event. Therefore only 62.5 gallons is consumed to move the first load, resulting in 40% less fuel to move goods. Other benefit include more profitable commercial fleets fewer trucks on the road and the ancillary additional congestion that consumes fuel from the surrounding traffic.

The above represents an idealized concept and this study is designed to investigate this proposition in detail. Questions investigated include the following:

- How long are the trips when the truck is empty?
- How does the length of empty trips compare to full or partially full trips?
- What percentage of freight VMT is actually empty?
- Do empty trips emanate from particular regions? Is this due to a lack of loads or poor matching?
- Are there particular sectors of the trucking industry that are prone to empty backhauls?
- Are there truck/trailer types that are prone to empty backhauls?
- Can empty backhauls be addressed through better utilization of tandems?

A key element in answering the above questions involves establishing a feasible means to identify if a vehicle is likely traveling fully or partially loaded. If a meaningful follow up to this study is to be performed (realizing the energy savings potential), then empty or partially full trucks must be identified for subsequent route analysis.

The following sections within this report will address these issues and how conclusions were arrived at.

EXPERIMENTAL DESIGN

The first phase of the study was establishing a means by which a specific truck is traveling empty or full by using data that is readily available from the majority of commercial vehicle messaging systems. Focus was given to semitrailers, FHWA Class 8 or greater operating over distances in excess of 30 miles.

The study focused on Class 8 trucks because they tend to travel over a wider region than other trucks and they naturally offer an increased opportunity to modify an empty backhaul route to obtain an opportunistic load. The economic activity of these trucks is such that often an entire trailer's worth of goods will be delivered to a single destination and the truck fully unloaded. Once unloaded the operator is faced with a decision to return to base empty or divert to acquire a paying load. This decision is primarily based upon the cost, measured in time and mileage, required to locate a load and divert to the secondary shipper and receiver. Paying loads that generate less revenue than the cost of labor, fuel, and equipment are simply not worth chasing. Therefore, knowledge of trends in routes that tend to empty trucks may offer planners or economic development professionals with opportunities for gains in efficiency.

Feasibility: An important element of this study involves arriving at a vehicle load detection methodology that is feasible in the existing operational environment. Economy of execution and reliability is necessary if routes which may have opportunities for load matching activities are to be identified on a regular basis. Trucks shift their activities in response to changing economic activities. A complaint the commercial goods carriers have voiced concerning many public sector attempts at assisting their operations is that the solutions are often behind the economic curve. By the time the solution is identified and implemented, economic activities have geographically shifted and reduced the value of the proposed solution.

Therefore, the means to identify where there may be load matching opportunities must be both economical and produce timely results. With this considered, the following techniques were discarded:

- **Fleet interviews** - While feasible for one a time study, this technique is expensive and generally an annoyance to the operators. Interviews also lack the accuracy that is necessary to identify specific route structures.
- **Travel diaries** - This technique is expensive and prone to errors. Significant time is necessary to keypunch the data if a paper diary is kept and equipment costs are high if performed electronically. Additionally diaries are a source of driver dissatisfaction and increased employee turnover. Commercial drivers are in demand and employment elsewhere can be readily obtained.

An approach which utilized the existing vehicle telemetry was arrived as the preferred truck monitoring means, as over 60 percent of the semitrailer fleets use vehicle messaging services. Many of these services provide value added metrics, such as fuel consumed, horsepower, and other variables that their fleet customers find useful for managing their internal operations. Calmar Telematic's HIVIS commercial vehicle telemetry database pools data from dozens of

fleets into a single resource and was extremely convenient for the study.

Challenge: While vehicle telemetry services readily tap into the engine's data bus, telemetry service providers provide a variety of metrics to their customers at varying levels of detail. In order to make a method of load determination feasible across many telemetry providers, a lowest common denominator approach was undertaken to identify which telemetry elements could be broadly accessed with a reasonable expectation of success.

Highly detailed data elements (engine horsepower being expended, etc) were discarded as telemetry service providers are inconsistent with their reporting or data availability. Per report fuel economy and similar breadcrumb related data are also inconsistently provided, but it was discovered that per trip fuel consumption is widely provided. Telemetry units often measure the fuel tank level and summarize the fuel consumed after the trip has ended. A trip end is generally defined when the vehicle is placed into gear and parking brake released at the beginning or the opposite actions when the trip is ending. At the conclusion of the trip, a report is transmitted that has A) an indication the trip has ended, B) the latitude/longitude of the trip end, C) date/time stamp and D) fuel consumed.

Therefore, the study team formed the following hypothesis:

A given truck with a given driver will consume more fuel when loaded than the same truck will consume when it is empty.

Other Considerations: Raw telemetry data is inherently "dirty" data in that it contains many reports that are of no consequence to this effort. When a vehicle is started, telemetry automatically begins to stream to the fleet dispatch center. Some of the data will be transmitted while still in the yard and some will be transmitted from the road. As a result, many telemetry data points are not of interest for this study. Examples include movements vehicles make within their marshalling yard or idling at a rest stop. Idling, while an energy consumption issue of its own, has no value in determining if the vehicle is empty or full.

Additionally, fuel economy reported by the telemetry is associated to a trip. By definition, this entails the two telemetry points that constitute the beginning and ending of a trip. Trip data is reported in a disassociated manner from the breadcrumb reports that occur when the vehicle is in transit. Since fuel economy is being postulated as the prime determinate of whether or not a truck is loaded, it is necessary to associate it with the route traveled (as defined by the breadcrumb reports) to determine the extent a route is running empty or full.

Specific data cleansing processes were developed to identify and filter out these unwanted telemetry data. Similarly, techniques were developed to associate the fuel economy per trip to each and every breadcrumb report to allow for association with a specific route.

INITIAL HYPOTHESIS TEST

Using telemetry data, two fleet types were selected for testing and random trips selected for testing the hypothesis. Specifically a fleet specializing in hauling petroleum products (fuel, etc) and one specializing in mixed goods destined for grocery stores were selected. These fleets were selected for the following reasons:

- Liquid goods are inherently very heavy products, as all of the cargo area is occupied by a liquid. In contrast, air is very light and indicative that no cargo is being carried. Therefore, it would be expected that the empty/full fuel consumption differential would be its greatest if the hypothesis were valid.
- Trucks carrying goods destined for a grocery store typically are mixed goods carriers. Grocery stores typically carry all manner of products, ranging from various food stuffs through paper goods and consumer products. Therefore, it would be expected that such load weights are variant and this variance allows for the strength of the subject hypothesis to be tested further.

Once the fleets and specific trips were selected, estimates were made concerning whether the vehicle was carrying a load or not. Vehicles were randomly selected and sample trips randomly selected. Concerning the vehicles that were selected, their fuel economy history was studied, as it was suspected that the fuel economy is individual to a specific vehicle (make/model, year, engine tune, etc) and a specific driver may be a factor. The empty/full estimates were then checked against interviews with the fleet managers concerning the specific trip in question.

Petroleum Carrier Results: As expected, the randomly selected trips were correctly estimated as full or empty. See Table 1. As the team expected, the larger weight difference between when the vehicle was full or empty made the fuel economy difference to be readily identifiable.

Table 1
Petroleum Carrier Empty/Full Estimation

Vehicle 1	average mpg:	5.63	Outcome
	Trip 1:	Start Time: 5/28/2009 6:29 End Time: 5/28/2009 8:27 avg mpg: 6.00 F/E guess: Empty	Correct
	Trip 2:	5/28/2009 Start Time: 14:40 5/28/2009 End Time: 17:09 avg mpg: 6.41 F/E guess: Empty	Correct
Vehicle 2	average mpg:	5.82	
	Trip 3:	Start Time: 5/28/2009 6:46 5/28/2009 End Time: 11:40 avg mpg: 5.50 F/E guess: Full	Correct
	Trip 4:	5/28/2009 Start Time: 12:59 5/28/2009 End Time: 14:25 avg mpg: 6.99 F/E guess: Empty	Correct
	Trip 5:	5/28/2009 Start Time: 16:17 5/28/2009 End Time: 21:18 avg mpg: 5.41 F/E guess: Full	Correct

Grocery Hauler Results: Table two shows equally promising results with the grocery hauler, however the simple technique was unable to discern that one trip was a less than truck load. It is not known *how much less* than a truck load was present in the particular trip or the nature of the cargo. (Could it have been of heavier goods? Lightweight goods?).

Table 2
Grocery Hauler Empty/Full Estimation

Vehicle 1	average mpg: 5.07		outcome
	Trip 1:	Start Time: 5/28/2009 4:33 End Time: 5/28/2009 7:08 avg mpg: 5.06 F/E guess: Full	Correct
	Trip 2:	Start Time: 5/28/2009 12:30 End Time: 5/28/2009 14:31 avg mpg: 5.61 F/E guess: Empty	
Vehicle 2	average mpg: 4.89		
	Trip 3:	Start Time: 5/28/2009 8:06 End Time: 5/28/2009 10:14 avg mpg: 5.68 F/E guess: Empty	Correct
	Trip 3:	Start Time: 5/28/2009 14:40 End Time: 5/28/2009 16:49 avg mpg: 4.12 F/E guess: Full	

Discussion: While the initial hypothesis test generally validated the approach, three issues stood out concerning the approach taken:

1. There were distinct differences in the average fuel economy for each of the trucks, empty or full. This raised the question of whether or not there was such variance in the fuel economy among vehicles as to require detailed fuel economy to be known for every vehicle. It is the team's opinion that such an outcome would be detrimental to arriving at an easily to apply technique for determining routes with many empty vehicles.
2. The difference in fuel economy between "full" and "empty" between the two types of cargo carried raised the question concerning whether or not principal commodity carried should be considered when estimating "empty" or "full" routes. Further review into this issue suggested that this should probably be carried at the one or two digit level detail of the standard commodity code classification scheme.

The reason for this decision lay with some commodities having incompatible container requirements (such as liquids verses solids), but even when the container is compatible the residual presence of the formerly carried commodity is incompatible with other goods. An example of this could be a fuel tanker truck as being inherently incompatible for carrying dairy products. Finally, commercial carriers are highly specialized at handling the general type of goods they carry. These carriers have well established customers in these industries and understand the market for freight. As a result carriers are inherently uncomfortable at handling goods that they are unfamiliar with for risk of handling errors and other unanticipated costs.

3. The sample used for concept testing was small and not statistically significant. While promising, more extensive testing and evaluation is required to arrive at a fully confident result. This limited test was in line with the scope of this early study and successful in avoiding extensive resources being expended upon a hypothesis that is likely to result in the null conclusion.

Conclusions: While the preliminary hypothesis test was promising, additional statistical evaluation is warranted to evaluate the procedure. Follow up testing should consider individual vehicle fuel economy differences and whether or not there was a way to avoid that detail level as a requirement. The commodity types typically carried should be considered too and the overall sample size greatly increased.

FOLLOW-UP TESTING

Vehicle and Fleet Characteristics: Trips among several commodity classes for the period between 3/8/2009 through 5/31/2009, totaling 22,831 trips were obtained for analysis. Table 3 summarizes these trips by predominate commodity carried, number of unique vehicles and number of trips. These vehicles and trips were screened to select trips that traveled 30 miles or greater and/or had reasonable fuel economy values (less than 15 miles per gallon per trip).

The minimum trip length was selected to provide a trip fuel economy result which included a range of driving conditions, grades, congestion, and engine heating. The result is a fuel economy reading that naturally averages out environmental effects narrowing the causes of variation to primarily work-load and driver performance.

Additionally, some of the fleets are also engaged in tandem truck activity on the New York State Thruway. It is a violation of the New York State vehicle and traffic laws to transport dual 48 ft trailers outside of designated routes, which generally involve only the Thruway and short spur routes to designated tandem yards. Therefore, the dual trailer make-up and break up activity by its nature requires empty trailers to be transported between nearby distribution centers/delivery destinations and the designated tandem lots. The minimum 30 mile distance designation helps to avoid these unavoidable empty back hauls from being introduced into the analysis.

Table 3
Fleet and Trip Characteristics

Goods Carried	Number of Vehicles	Number of Trips
Dairy	5	132
Petroleum	76	6986
General (For Hire Common Carrier)	99	6610
Grocery	74	8728
Heavy Equipment	13	375
Total	267	22,831

Other criteria employed in selecting the vehicles is that they A) had to be domiciled within New York, B) significantly traveling on New York State Highways and C) operate within geographic overlapping boundaries. These three criteria team's requirements that 1) the principle activity occurred in a contained geographic area that would help to reveal if overlapping routes containing significant empty vehicle travel is occurring and 2) respect that this is a New York State sponsored study, whose results if proved to be promising, could be followed upon to the benefit of this study's sponsors.

Initial Analysis: The data was initially analyzed in a total disaggregate manner, only keeping the vehicle ID as the constant cohort. The hope in following this approach is that a commonality could be found concerning a means to identify empty/full could be done such that it does not require the primary commodity carried to be known. Extensive testing resulted in the null hypothesis to be found. When considered as a population sample, the fuel economy analysis resulted in a random distribution.

This hypothesis failure suggested that commodity type carried was an absolute necessity in determining the whether a vehicle is running empty, partially full or completely full. When tested against weekly, monthly or study period averages, weekly statistics failed to show any meaningful pattern. For any given truck by commodity type carried, there is too much random activity to discern with certainty if a truck is full or empty. The reason for this issue is that any given truck is making statistically insignificant trips during a week. The average is 13 trips, indicating that about 2 trips per day are being made on the whole. Sometimes it is full every trip (fleets do attempt to optimize their income per cost to move the truck). However other days, the truck seems to be running empty all of the time.

Long- Term Analysis

Monthly: When reviewed from a monthly standpoint, the data stabilized among each of the commodity cohorts being evaluated with sound patterns, such as goodness of fit, students T-test and other relevant statistics, revealed stable per trip fuel consumption patterns. This is useful to determine if empty or full trip making is occurring. The particular month analyzed was during May 2009.

This initial success lead to the further question of whether or not the entire sample being considered (March 2009 – May 2009), almost an entire quarter year would reflect the same level of stability. A student's T-test analysis concerning population differences revealed that there is almost no difference between the two populations. This suggests the economic pressures that drive commercial fleet activity is sufficiently stable over the short term to allow opportunistic load matching activity to be feasible.

Per Truck Fuel Economy Variability

It was noticed that fuel economy varied on a per truck basis. This variability is to be expected with the mix of truck makes/models and the mix of driver skill that is the reality for most fleets. Fleets are continually seeking new equipment for reasons of performance, reliability and capital costs. Therefore, it is a rare fleet that has a single make/model and drive train for all of their trucks. Additionally, the majority of fleets in the study practiced a policy of one-driver-one-truck. Driver performance is known to contribute to fuel economy shifts of as much as 10%. Therefore, two identical trucks with different drivers should be expected to have different fuel economy. While these variations may seem to confuse the issue, a single driver with a single truck should behave in a consistent manner with the primary variation being the load in the truck.

These issues were evaluated in detail, beginning with a per truck fuel economy analysis. Figures 1 and 2 provide an example of this per vehicle variance for a grocery carrier. Similar variances were observed for other fleets and primary commodity carried.

Figure 1, One Grocery Carrier Vehicle Fuel Economy

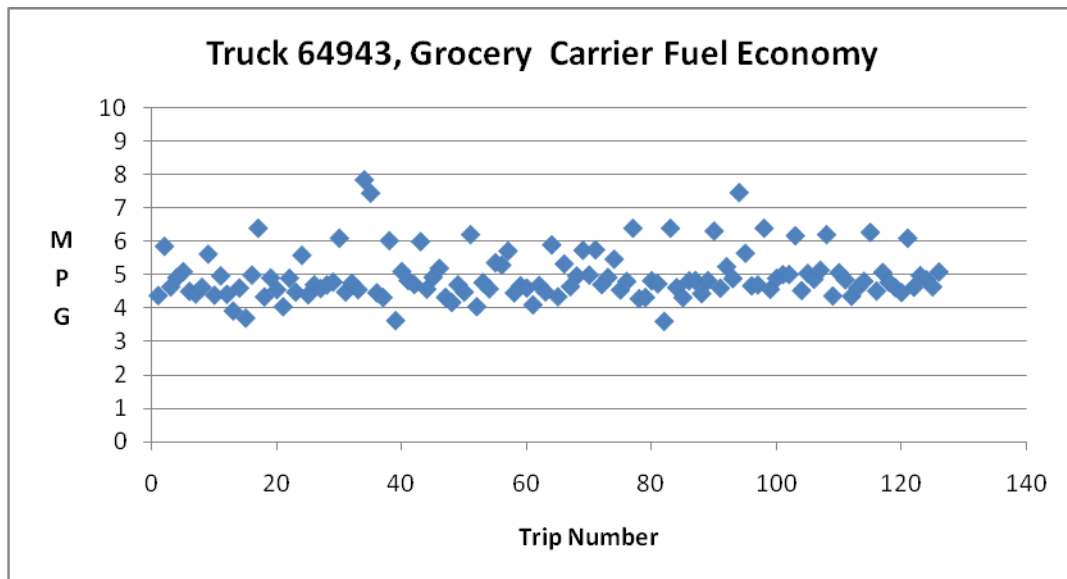
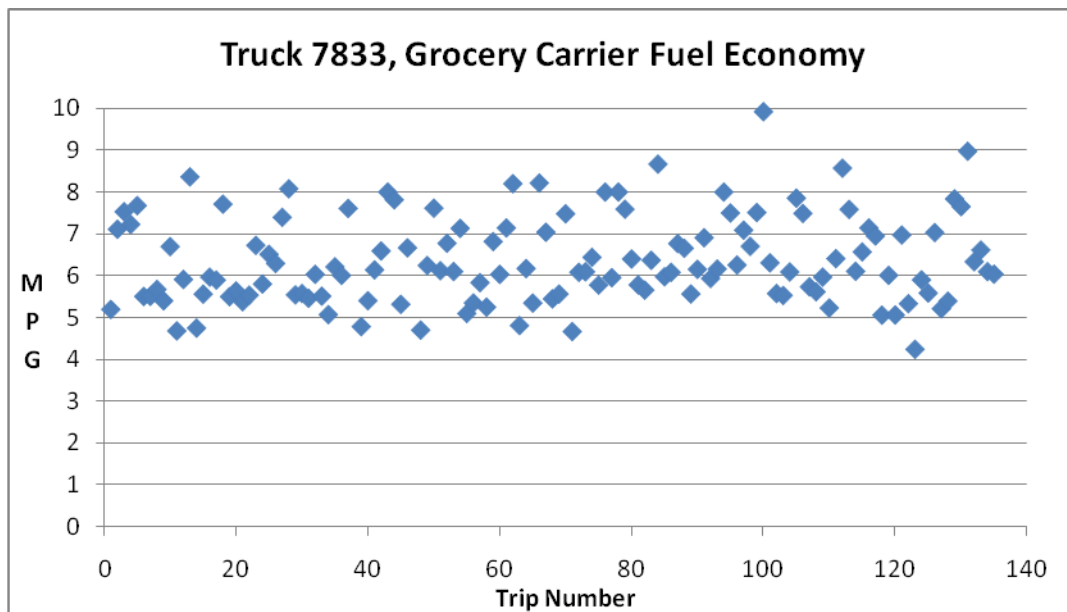


Figure 2, Another Grocery Carrier Vehicle Fuel Economy



This issue was investigated further, by evaluating the fuel economy variance of each vehicle by commodity type. It was shown on a per vehicle basis, stable high and low fuel economy was

noted in relation to an individual vehicle's average fuel economy. Figures 3 through 7 illustrate these per vehicle fuel economy usage patterns.

Within each chart, individual trucks were given an identifier (horizontal axis) and the departure from the vehicle's average fuel economy was plotted.

Figure 3, Dairy Carrier Fuel Economy Variance by Vehicle

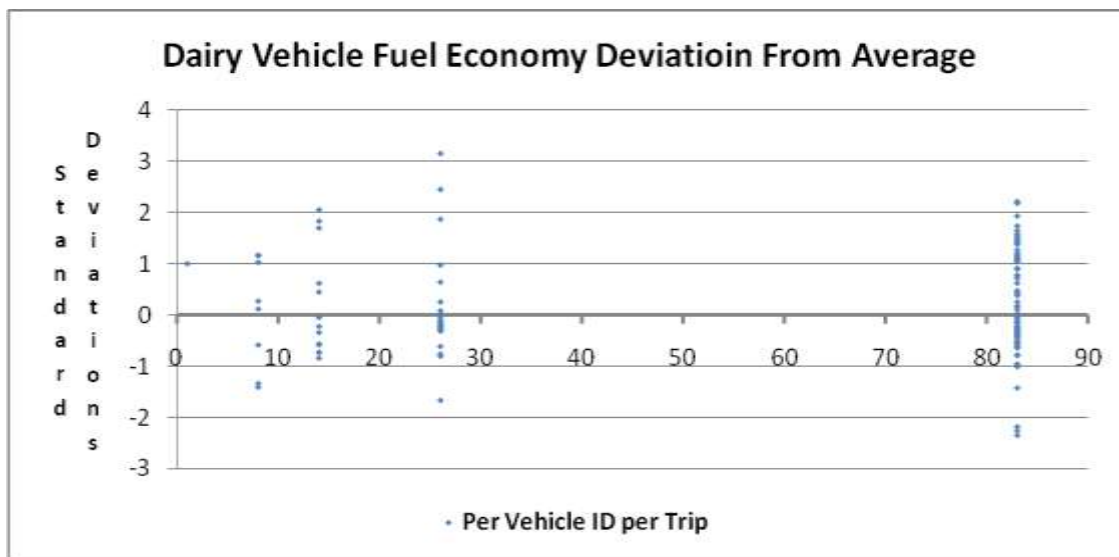


Figure 4, Heavy Equipment Carrier Fuel Economy Variance by Vehicle

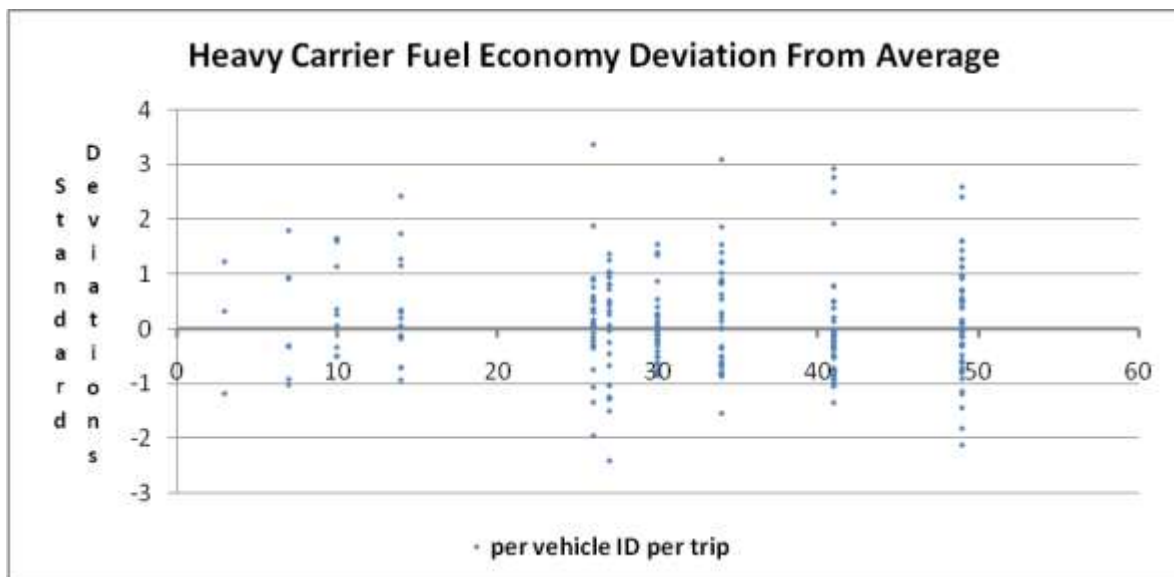


Figure 5, Grocery Carrier Fuel Economy Variance by Vehicle

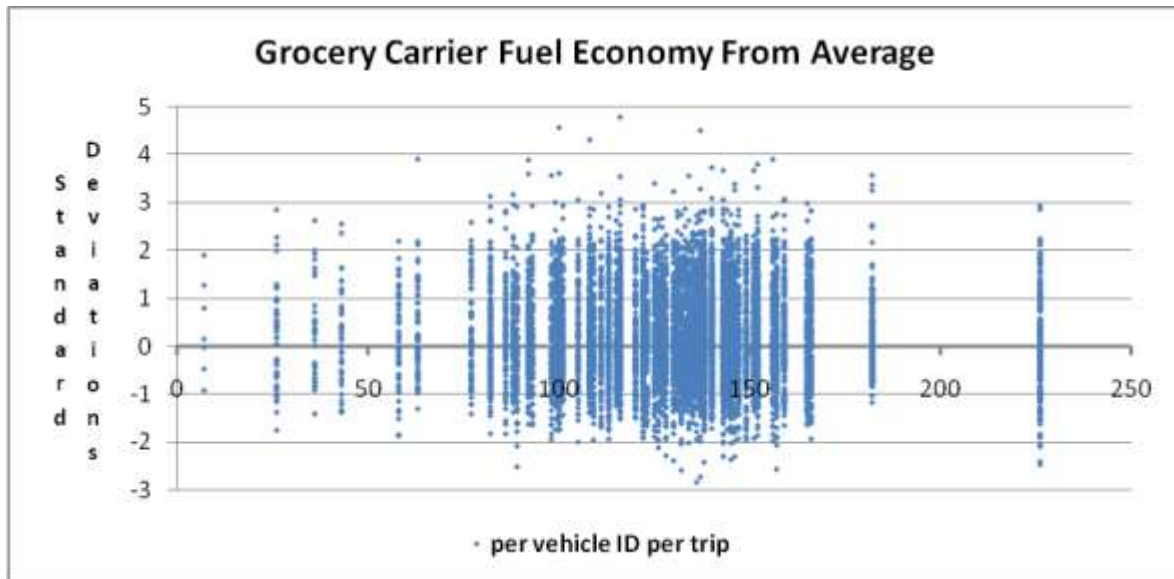


Figure 6, General Carrier Fuel Economy Variance by Vehicle

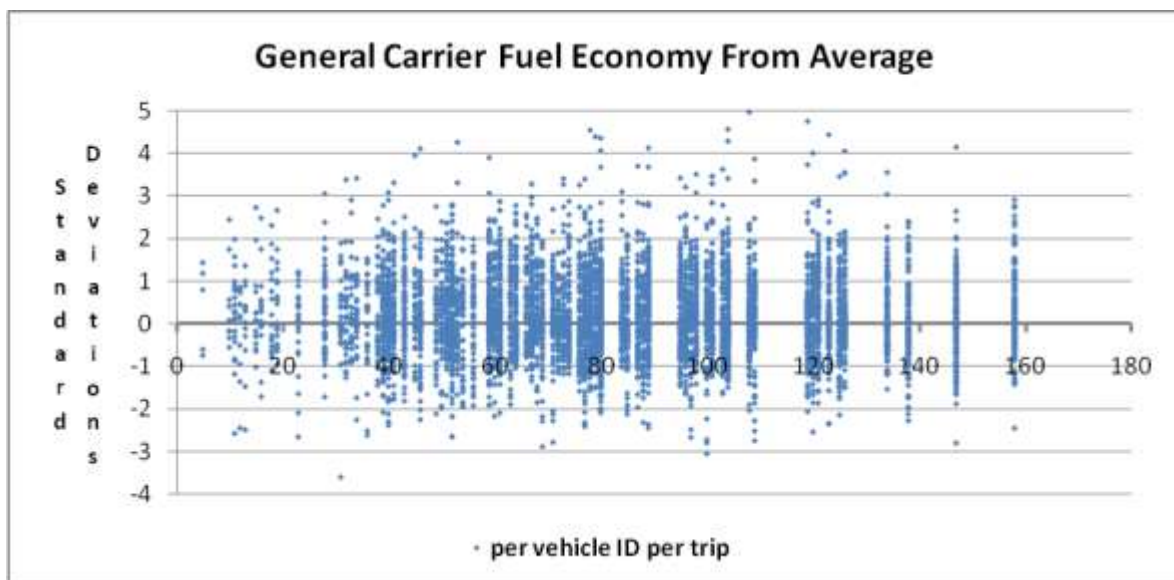
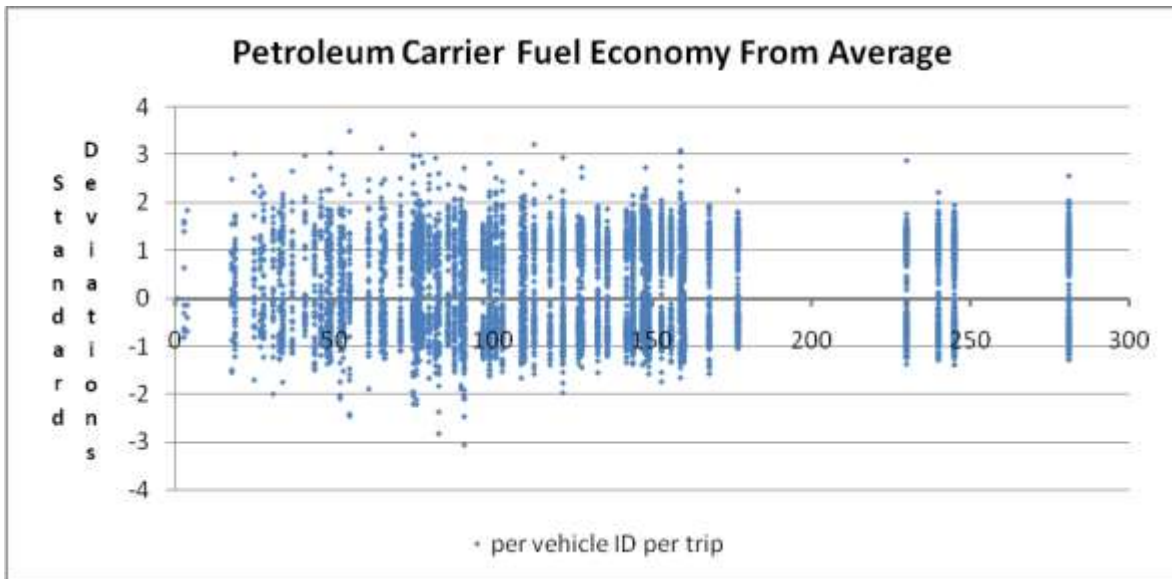
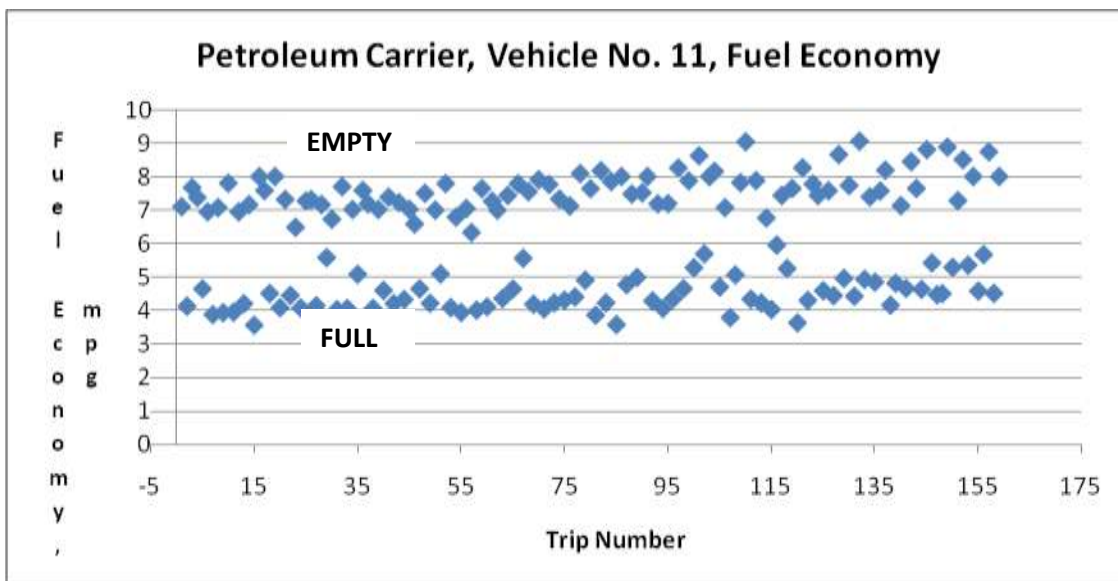


Figure 7, Petroleum Carrier Fuel Economy Variance by Vehicle



These figures illustrate that there is a considerable variance among the carriers of specific commodity types. Within each commodity type carriers, there is a slight tendency for most

Figure 8, Select Figure 7 Drill Down Detail



vehicle to have a per trip fuel economy that is in the positive range above average. Additionally, while there is per vehicle variance, they tend to fall within a common range among commodity groups.

Figure seven also shows fuel economy for the petroleum carrier as being stratified into two groups with a clear break between them. This is because the petroleum carrier tends to load the truck at a depot and carries it full to a single destination (local depot for smaller trucks to make retail deliveries) or among a series of retail establishments (e.g. gasoline stations). Petroleum is by nature a heavy load and when the truck is empty, a marked change in fuel economy occurs. See figure 8 as a detailed view from a truck randomly selected from Figure 7.

Summary: The primary commodity carried is an important cohort for determining if a truck is running empty or not. Concerning individual vehicle fuel economy variance, this is relatively unimportant for determining fuel/empty routes provided that a robust population is present.

Commodity Carried Fuel Economy Variability

The discussion above revealed that commodity carried is an important factor for determining whether or not a truck was empty. It does not necessarily reveal what the fuel economy variance threshold should be to reliably estimate if a truck is likely to be running empty or full. Therefore, a population analysis was performed whose emphasis was to look at the fuel economy variance across all trucks within a specific commodity group.

The initial step in this process was to determine what the basic population characteristics were. Basic descriptive statistical analyses were performed to outline these groups. The characteristics are shown in Table 4 below:

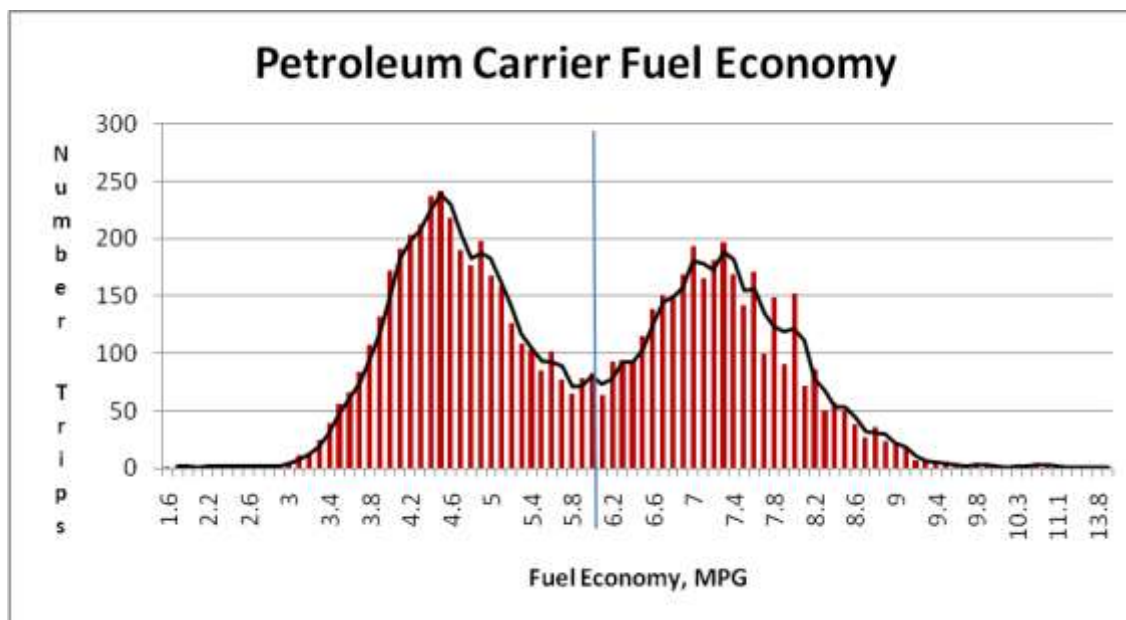
Table 4
Fuel Economy (MPG) By Carrier Type

Carrier Type	Number of Trips	Average Economy	Confidence Interval			Median	Standard Deviation
			95 %	Low	High		
Dairy	132	4.80	0.19	4.62	4.99	4.27	1.30
Petroleum	6986	5.87	0.03	5.84	5.90	5.71	1.50
General	6610	6.36	0.03	6.33	6.39	6.24	1.43
Grocery	8728	5.40	0.02	5.38	5.42	5.31	1.10
Heavy	375	5.74	0.16	5.58	5.90	5.61	1.86

The statistics support the earlier finding that the average fuel economy does considerably vary among the type of commodity carried. It also shows that the average value is very strong as the 95% confidence is a low percentage value in all cases. However, the relatively large standard deviation shows that there is considerable per trip fuel economy variance. Moreover, the median fuel economy, while close to the average in most cases, is always less than the average. This level of skewness suggests that the trips tend to be more than likely less than average, implying that more than half of the trips are carrying a load.

When graphically reviewed from a population distribution, askewness to the left is shown in many carrier types. Figure 9, shows an exception for petroleum carriers, as by nature of operation the trucks tend to have an even distribution of full and empty trips.

Figure 9, Sample Distribution of Petroleum Carrier Fuel Economy



This pattern is different for the other commodity carriers. For more generalized carriers a definite left skewness of the curves indicates that the fleets tend to optimize their truck movements on a paying basis (e.g. have them carrying a load). See figures 10 through 13. It is significant to note that the mpg threshold signifying a probable empty trip vary by primary commodity carried. The reason for this most likely lay with the weight characteristics each type commodity a carrier transports.

Clear inflection points in the fitted curves on the fuel economy histograms show a sharp increase in fuel economy (See Figures 14-18). The team has interpreted that, in general, little or no cargo is being carried at these inflection points. Review of the population distribution of trips by commodity carried shows that the majority of trips are unambiguously running empty. These tend range between ten to thirty percent of all trips, with a tendency for this to fall around twenty percent of trips by the commodity types studied. A significant exception is found with Petroleum carriers. Nearly 50 percent of their trips are empty. While most definitely empty trips are a minority of the trips, this is not a trivial value as they represent several million VMT per year.

Figure 10, Sample Distribution of Grocery Carrier Fuel Economy

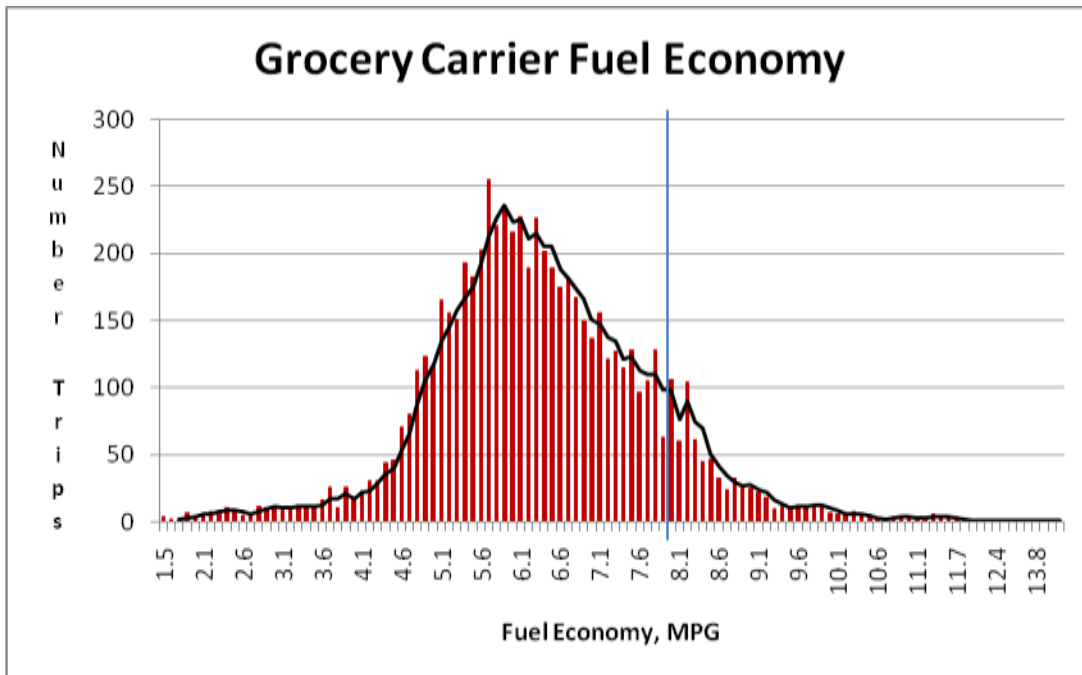


Figure 11, Population Distribution of For Hire Carrier Fuel Economy

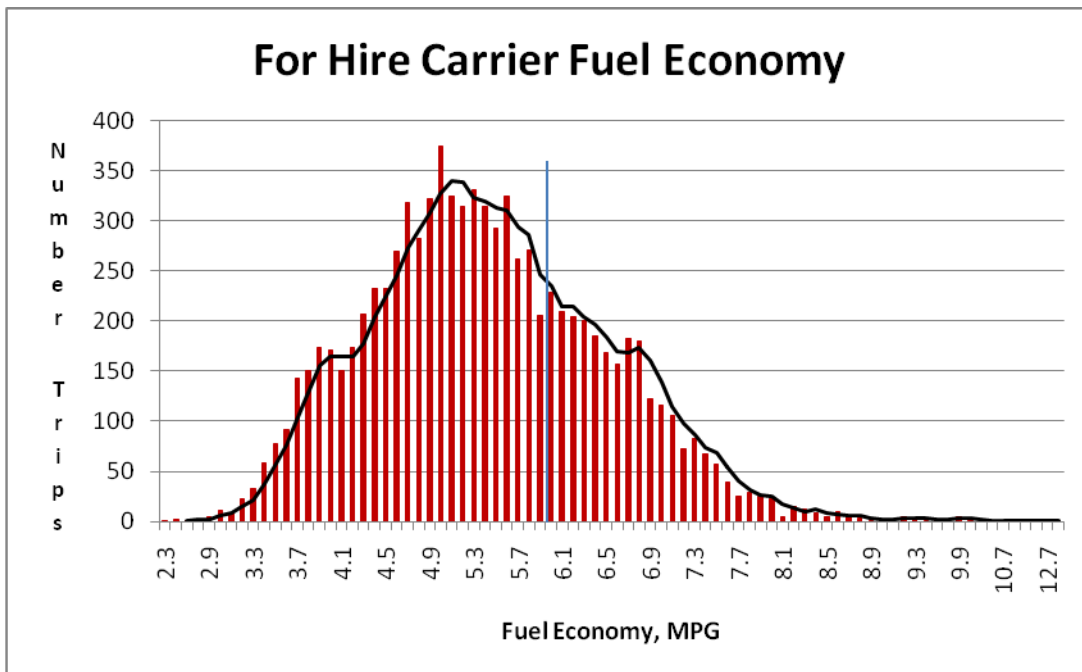


Figure 12, Sample Distribution of Dairy Products Carrier Fuel Economy

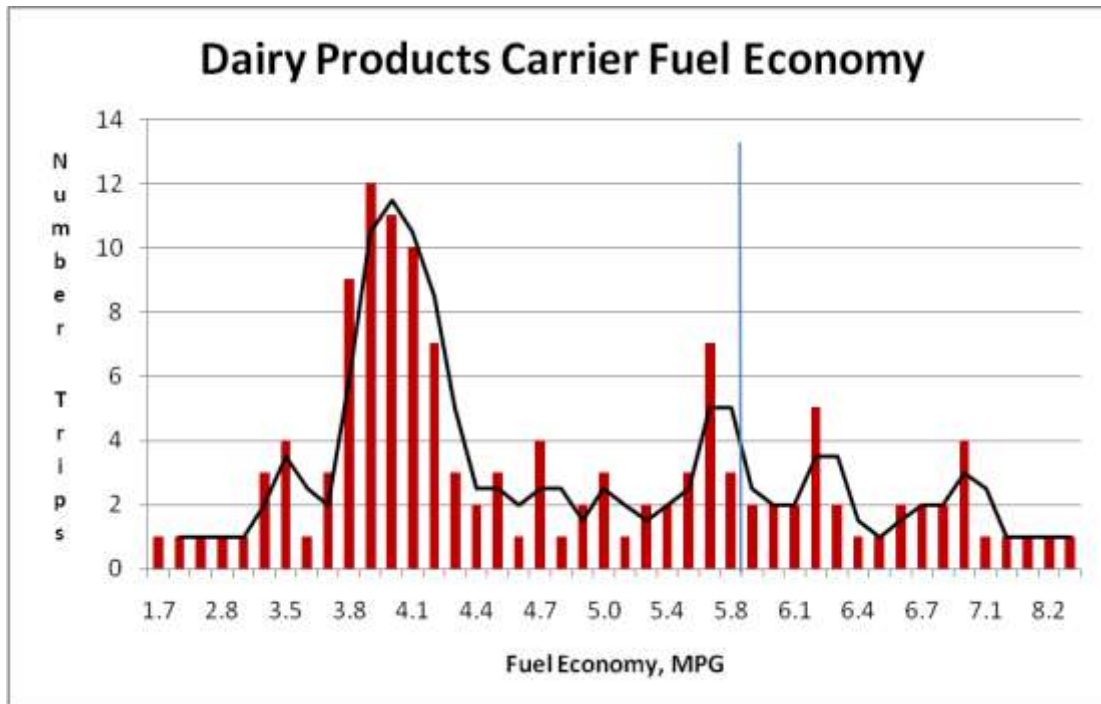


Figure 13, Sample Distribution of Dairy Products Carrier Fuel Economy

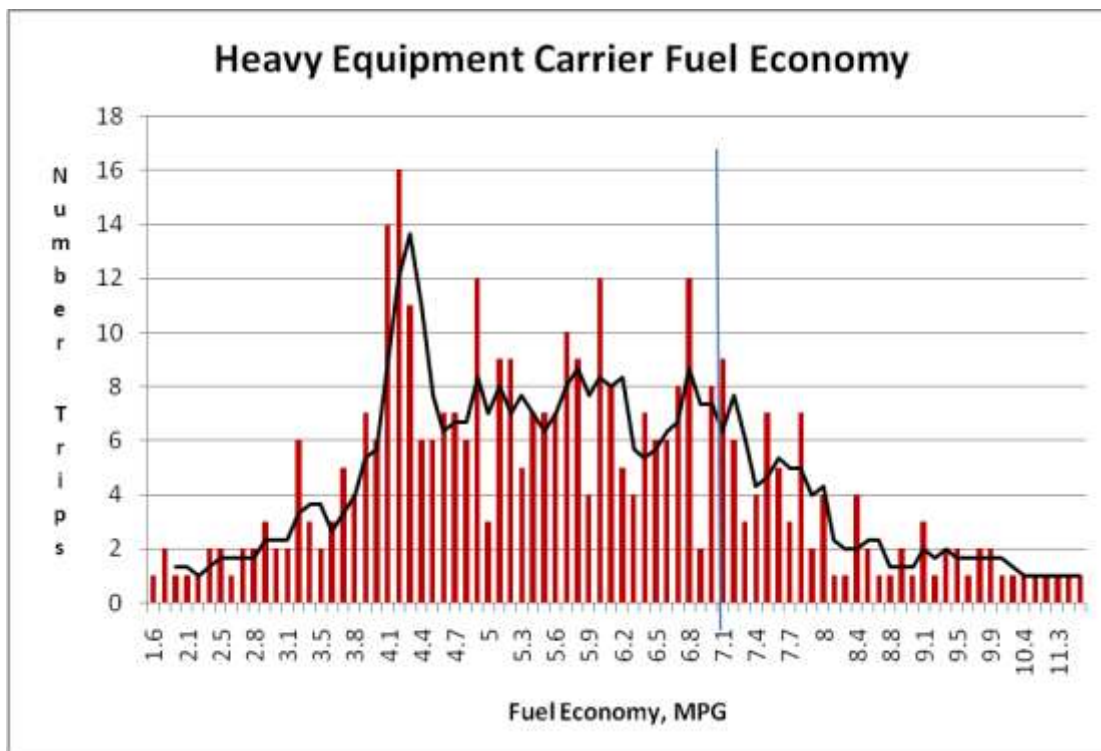


Figure 14, Probable Empty Grocery Carrier Trips

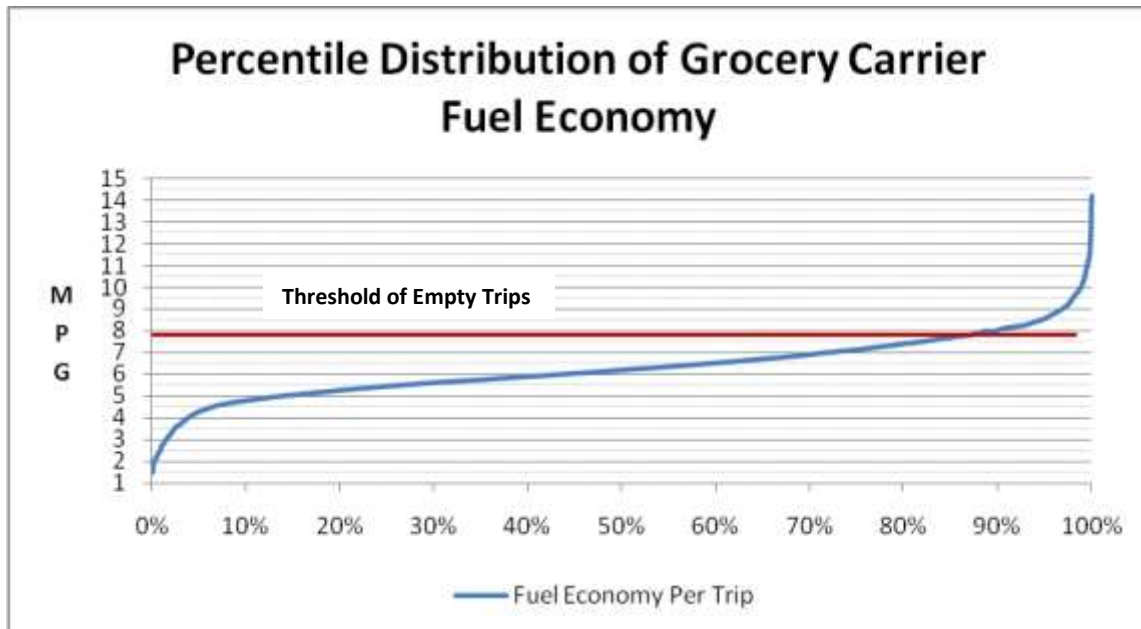


Figure 15, Probable Empty For Hire Carrier Trips

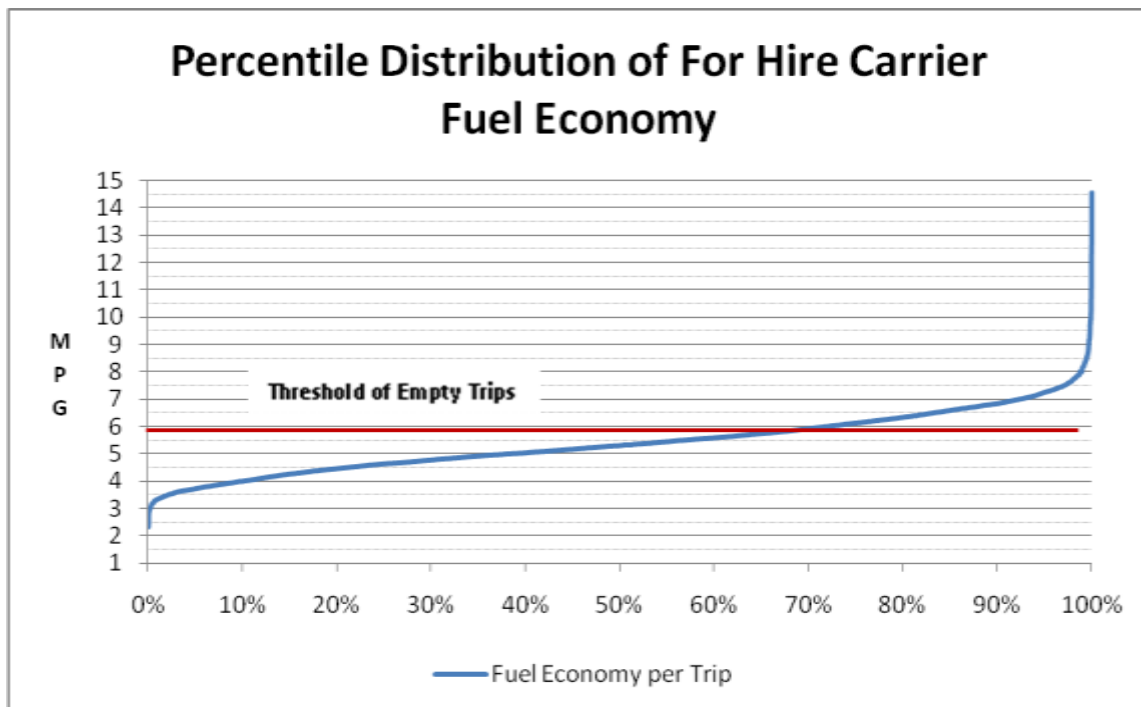


Figure 16, Probable Empty Dairy Products Carrier Trips

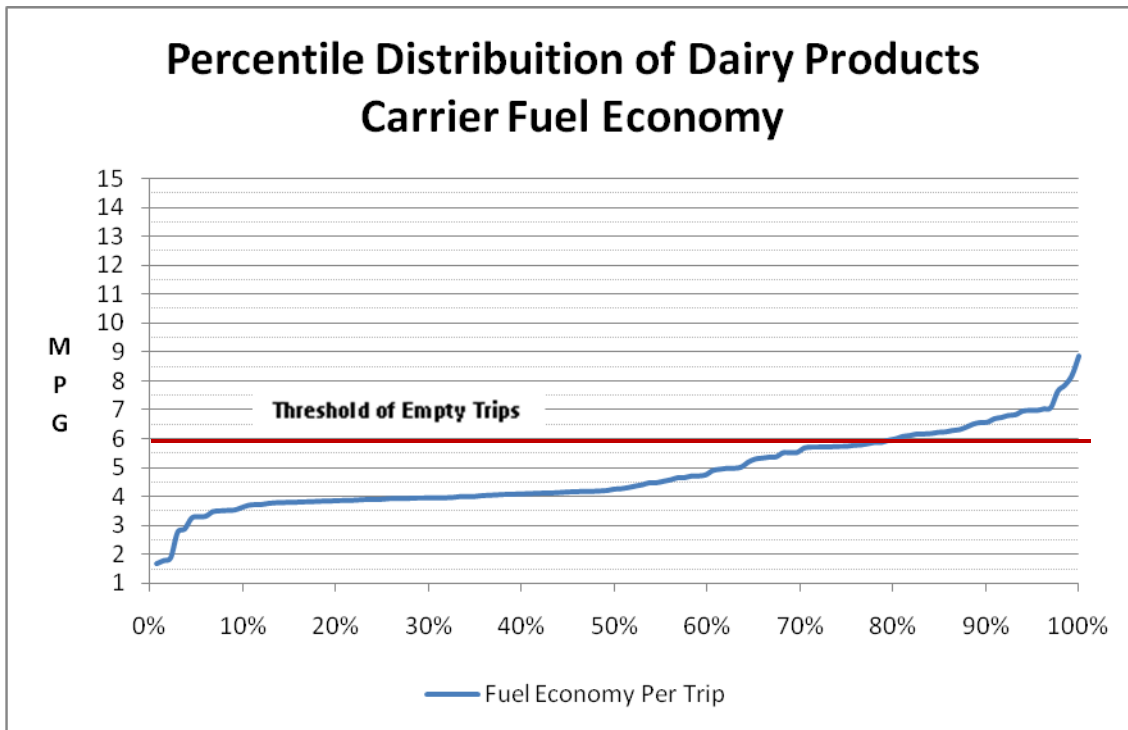


Figure 17, Probable Empty Heavy Equipment Carrier Trips

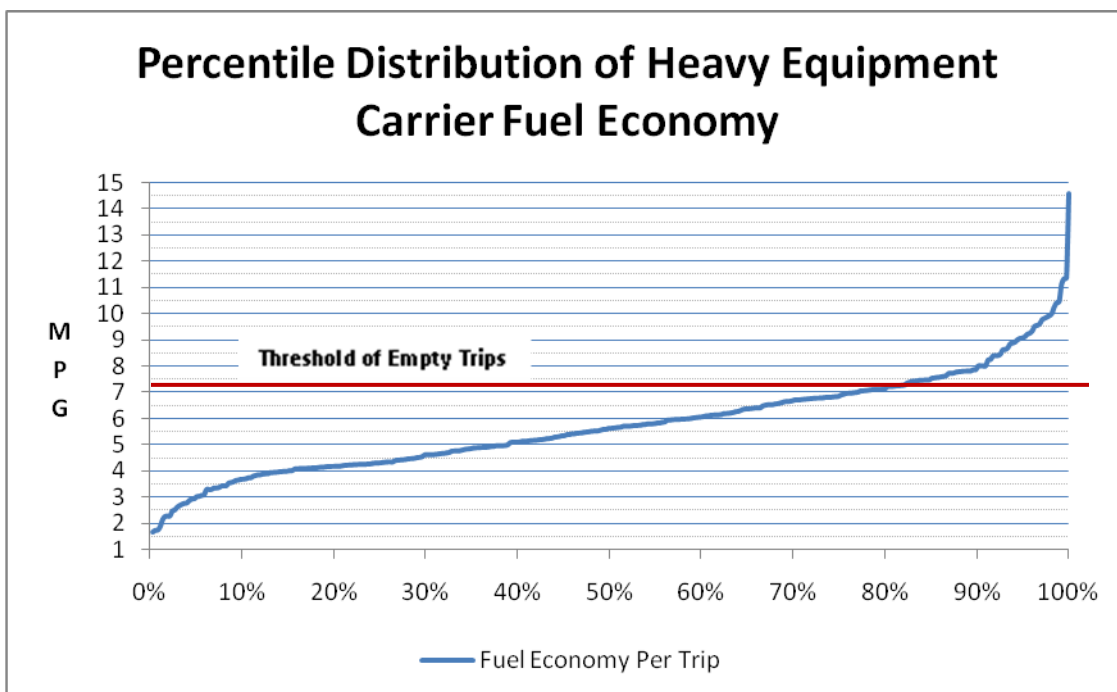
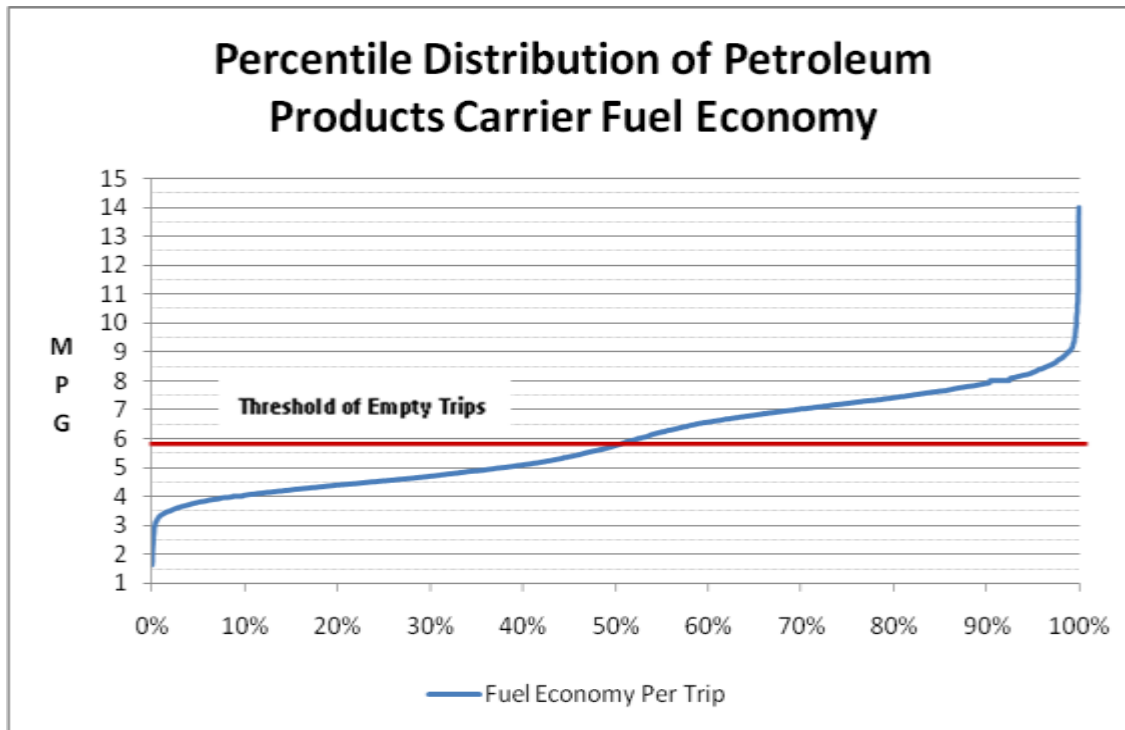


Figure 18, Probable Empty Heavy Equipment Carrier Trips



FINDINGS

- Fuel economy aggregated over a trip can be used to identify if a vehicle is operating with a full/partial load or is empty.
- Primary commodity carried is an important indicator for determining if a truck is operating empty or full. With commodity known and understood, fuel economy alone is a reliable indicator of determining if a truck is likely to be empty.
- Weekly commercial fleet activity is unstable indicator if an opportunistic load to earn income can be obtained along a given route. Monthly or quarterly time periods provide a stable indication if trucks are empty or loaded.
- While there may be nontrivial fuel economy variance among trucks within a commodity group, when evaluated as a collective group among a commodity type carried, representative fuel economy patterns are present.
- The fuel economy threshold signifying a likely empty trip varies by commodity typically carried by a fleet.

- Probable empty trips represent ten to thirty percent of all trips. Twenty percent represents the mean.
- Over the course of a month and a quarter the trucks are traveling sufficiently empty as to be available to obtain opportunistic loads to be picked up for financial gain of the fleet operator.

APPLICATION

With known fuel consumption threshold values available to identify empty backhaul trips, trip length characteristics were reviewed to determine if there were any behavior differences between empty or non-empty trips. In general, empty trips were slightly shorter, but well within any mileage deviation that a non-empty trip will tend to travel. The summary level comparison shown in Table 5 suggests that empty trips are just as apt to travel long distances as full/partially full trips will. The implication is that the ability to garner an opportunistic load is present in many instances, putting fuel burnt to productive uses.

Table 5
Miles Traveled, Loaded vs. Unloaded

Carrier Type	Not Empty		Empty	
	<u>Miles Traveled</u>		<u>Miles Traveled</u>	
	Average	Standard Deviation	Average	Standard Deviation
Dairy	63.6	35.3	59.9	32.5
Petroleum	68.6	36.5	65.6	31.6
For Hire	109.1	73.9	80.1	57.2
Grocery	100.1	55.1	89.3	52.2
Heavy	60.8	30.3	56.9	33.2

This raises the question of where the trips are plying. Routes with extensive empty vehicle usage are more likely to be able to develop the ability to garner opportunistic loads than routes that occasionally have an empty vehicle. The following figures provide mapping of the individual routes that experience empty vehicle travel by varying frequency for all carrier types studied. These figures are oriented to provide the reader a sense concerning the percentage of backhaul trips that are occurring and their relative magnitude as they pertain to studied sample.

Note, relatively few trips are shown to be occurring in the New York City metropolitan area. This is because the fleets surveyed do not have downstate activities in any significance and therefore, the reader should not interpret the study is suggesting that there are few empty trips there.

Figure 19 shows that empty backhaul activities are occurring throughout the state. Nearly all of the interstates have significant quantities of empty trips occurring, although the percentage may be relatively low on certain route segments. The low percentage should not be discounted, as the number of trips is still large. Detailed review of the GIS mapping, not visible in these figures provided herein, reveal that a large number of secondary highways also receive a large percentage of empty trip activities. However their numbers are sufficiently low as to suggest that such trips are incidental in nature, implying that even if an opportunistic load is available, a truck may not be in the vicinity to pick up the cargo.

Routes of significant distance showing quantities of empty backhaul activities include the following:

- I-87, between Plattsburgh and Suffern;
- I-81, entirety;
- I-90, between the Massachusetts border and Interchange 61.
- I-88, entirety;
- I-390, entirety;
- I-86, between Binghamton and Elmira;
- I-84, between I-86 and I-87;
- NY 8, between Utica and I-88;
- NY 12, between Watertown and Binghamton;
- NY 7, between Massachusetts and Schenectady;
- NY 149 and NY 4 corridor between I-87 (Northway) and Vermont.

What is not shown on the figures is the revealed directionality present on many of these routes. For example, I-87 between the Canadian Border and Thruway Interchange 24 generally has as much as twice the number of empty southbound trips than northbound trips (though this may be due to the exclusion of Canadian carriers in the study). Such load disparities are present on other routes as well, including much of the New York State Thruway (I-87 and I-90 portions) and I-88.

These directionality differences generally implies that opportunistic load matching may have to consider the general direction the opportunistic load is destined for in relation to the opportunity of identifying a nearby vehicle that may be able to pick up the load. Simply, there will be greater opportunity on routes traveling one direction verses the opposite.

Figure 19, Routes with Empty Trips and Their Significance

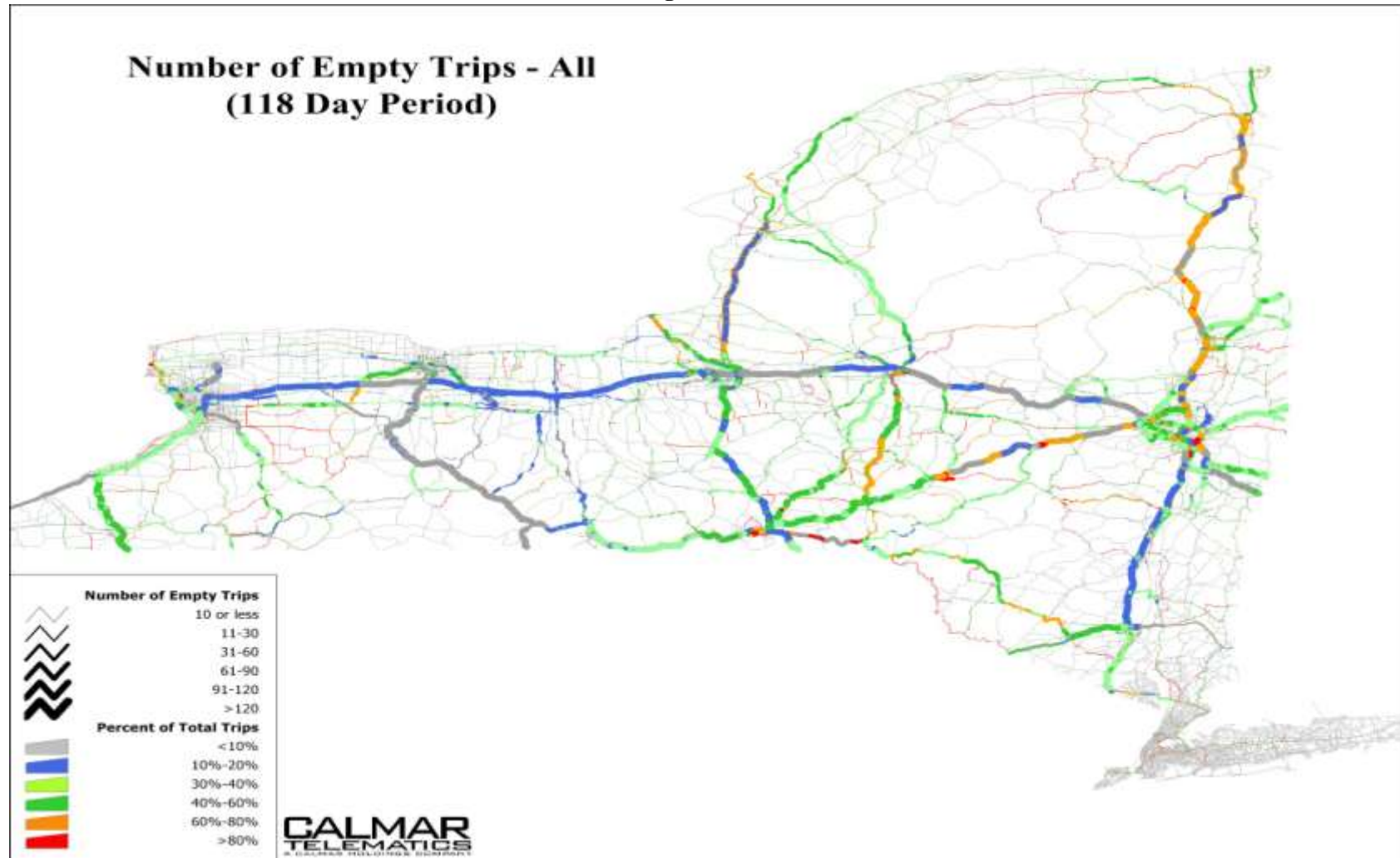


Figure 20, Routes with Empty Grocery Trips

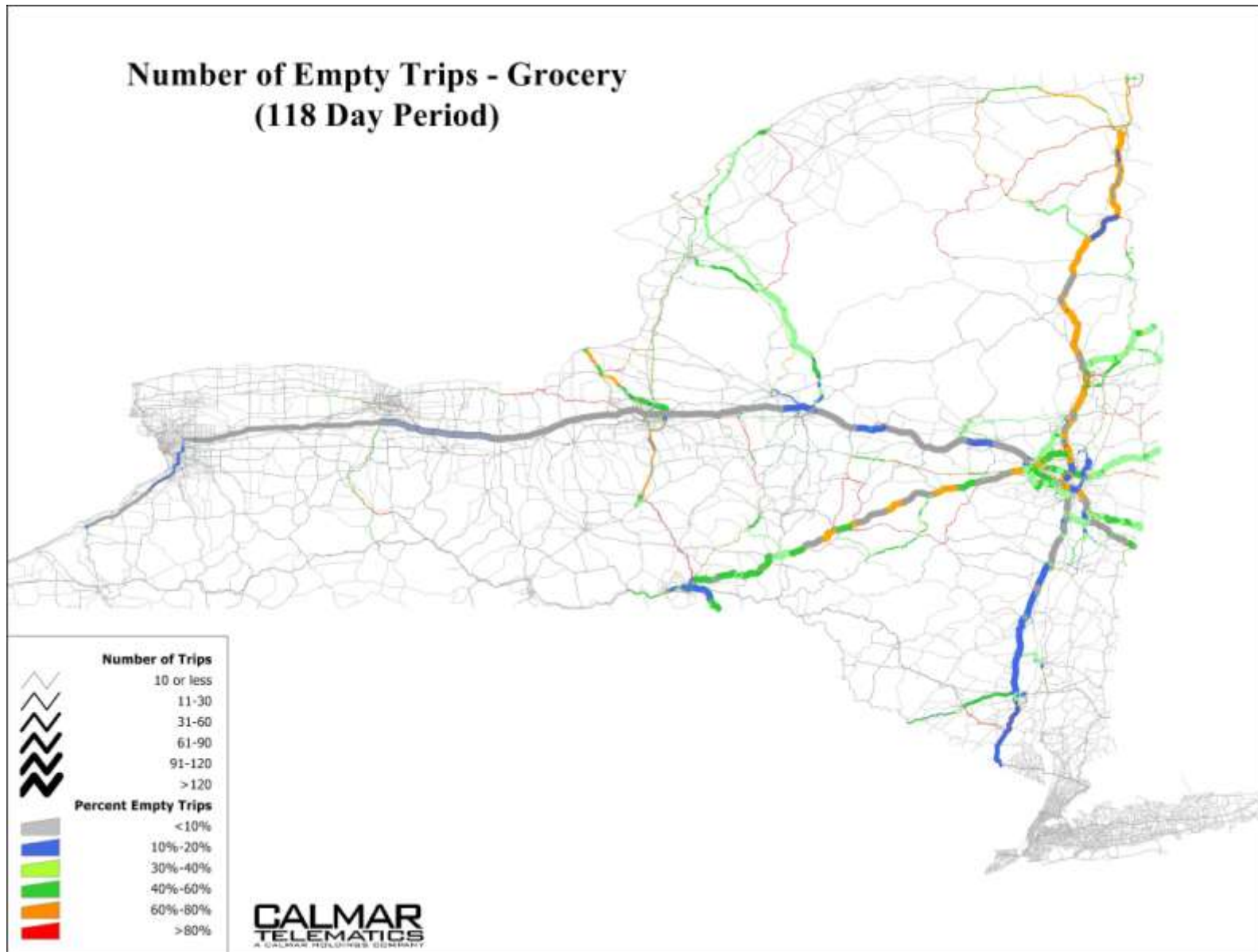


Figure 21, Routes with Empty Petroleum Products Trips

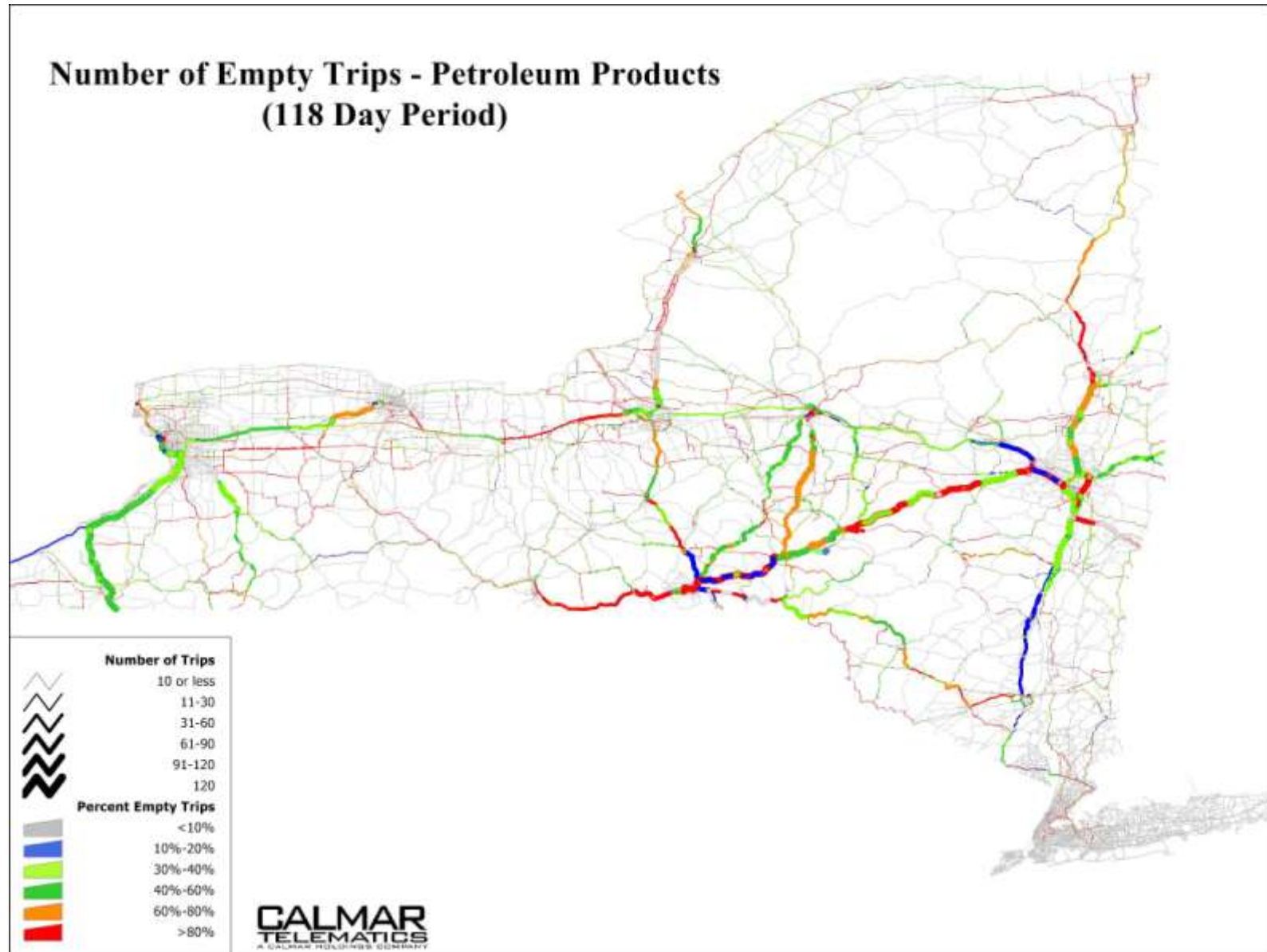


Figure 22, Routes with Empty For Hire Carrier Trips

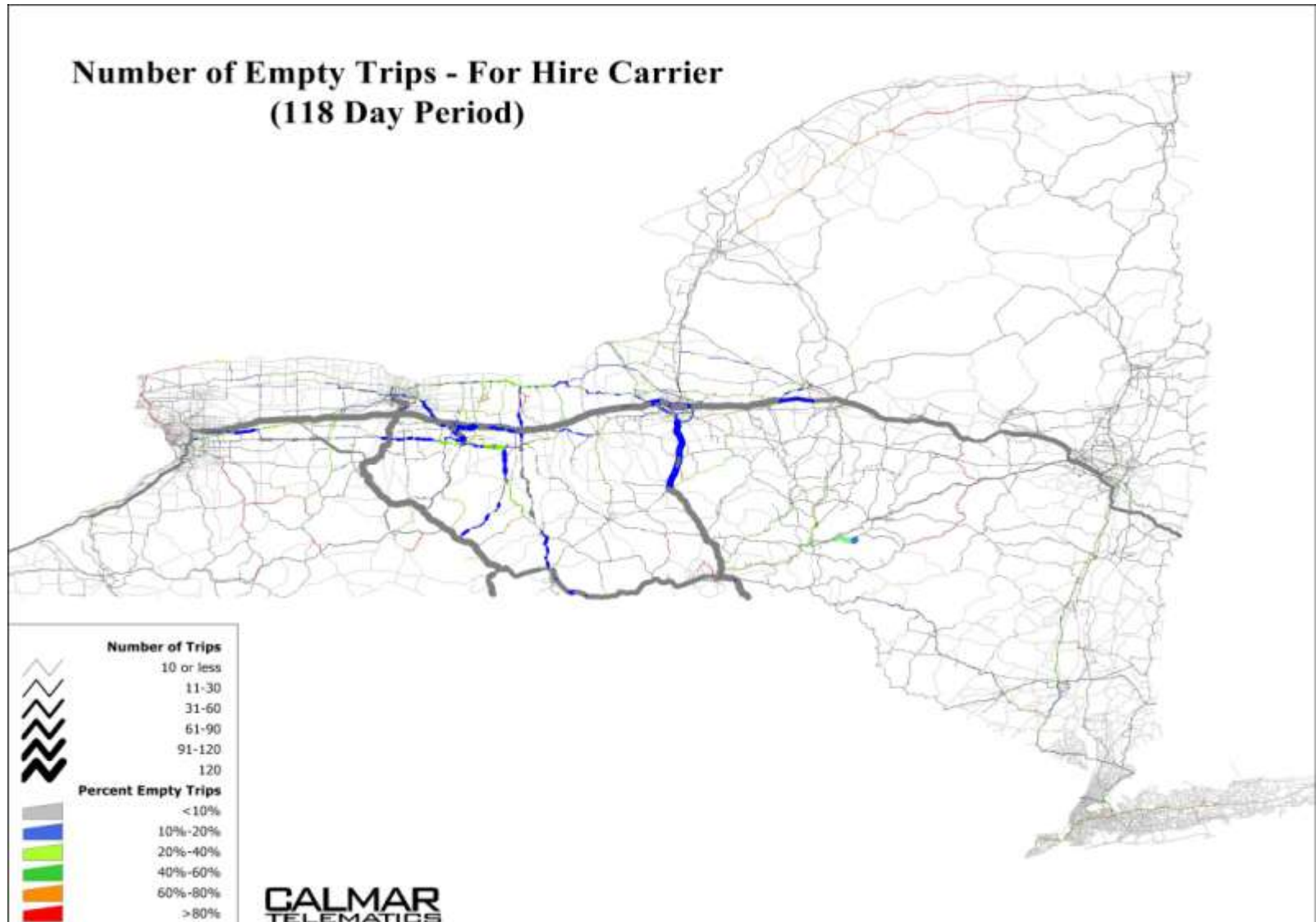


Figure 23, Routes with Empty Heavy Equipment Carrier Trips

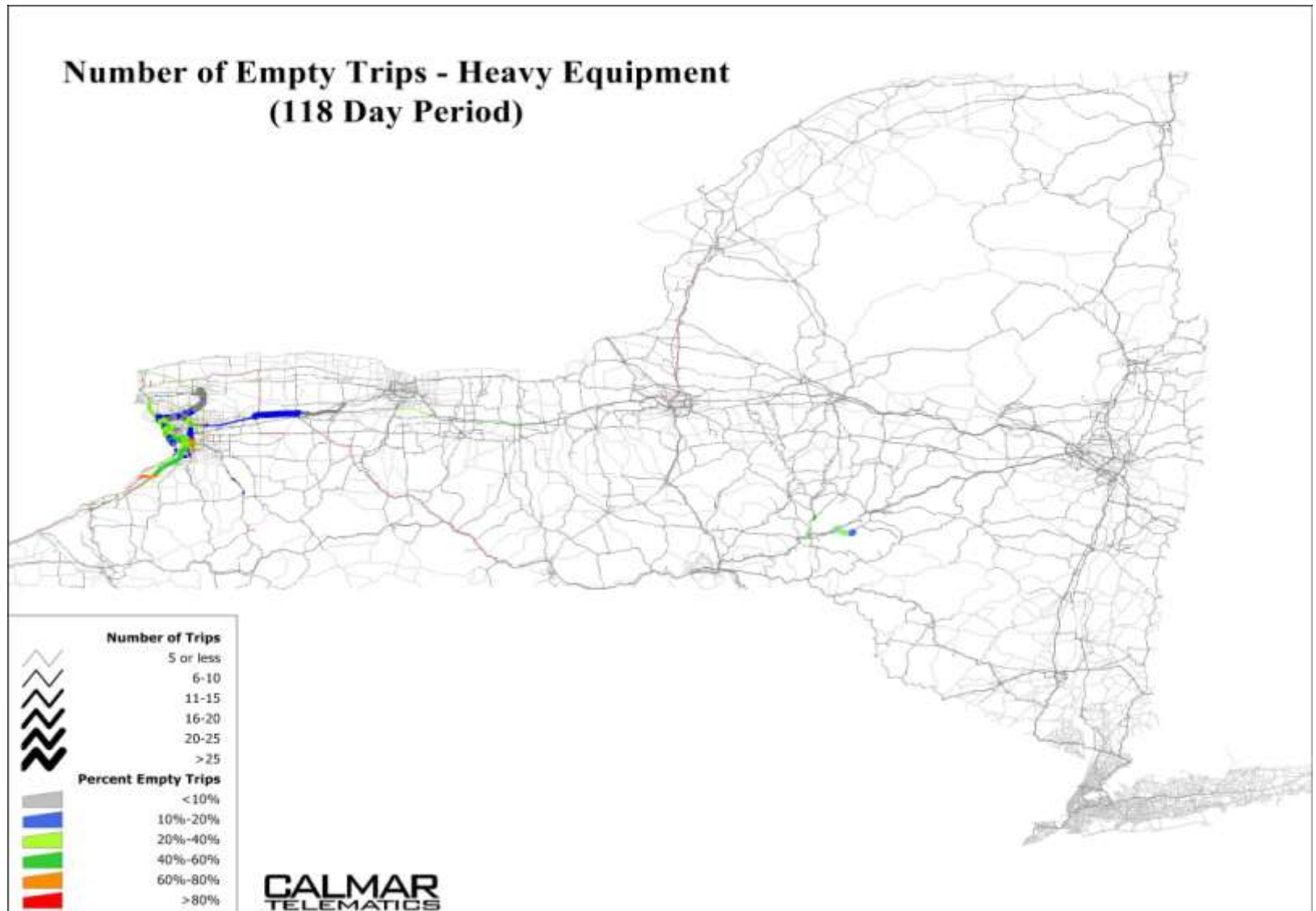
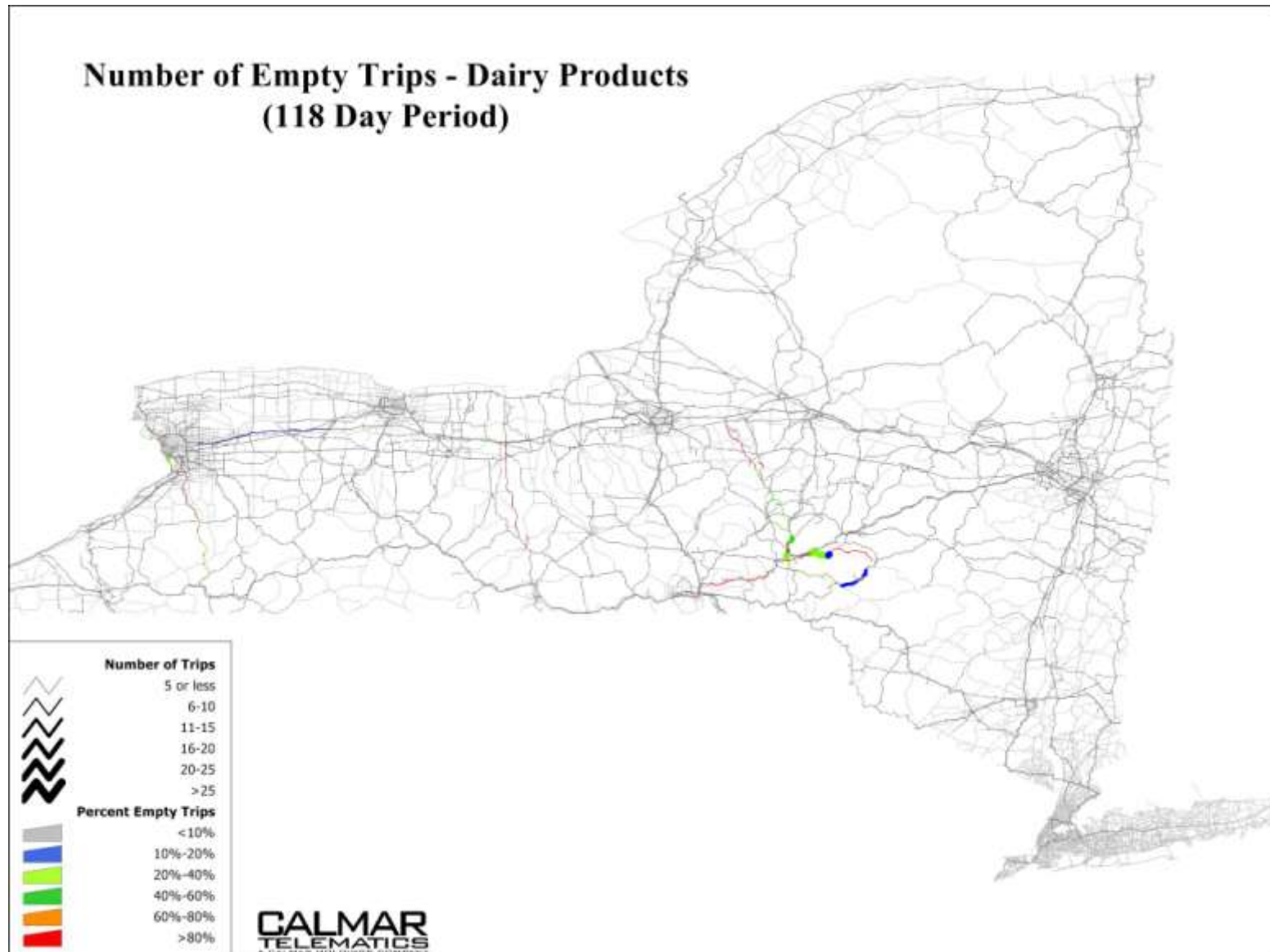


Figure 24, Routes with Empty Dairy Products Trips



CONCLUSIONS

1. For sufficiently heavy loads, it is practical to identify load status for trips for a truck on a given day.

The study concluded that sufficiently heavy load conditions such as bulk liquids can be identified for an individual truck for any specific day.

2. It is practical and reliable to determine if a trip includes a heavy or light load.

The study concludes that it is very practical to determine if a trip occurring over a period of time for a given sector of goods being carried are empty or not based upon fuel economy alone. The principal reasons why this is practical and reliable are:

- a) Groups of drivers will tend to fall around a central norm of quality and skill when considered as a population (creating a norm in fuel economy).
- b) The types of cargo predominately carried tend to have an average weight characteristic which is a stable indication of the amount of fuel required to move the load. The need to know the actual weight is not needed, provided that the class of cargo predominately carried is sufficiently narrow.

3. A month or greater of fleet monitoring provides a stable indication of where the empty or full loads are occurring.

Monitoring the fleet's movements and fuel economy characteristics indicated that there is a flux of light or heavy movements on a daily basis. Using the generalities described in Conclusion 2, it is evident that on some days a given fleet's trucks may be predominately either light or heavy. These differences apparently occurred on a random basis and are likely a reflection of the variant business levels that naturally occur on a day to day basis. Similar variation was observed during any given week when compared to another week.

However, trends became stable when a month and quarter year timeframes were evaluated. This is likely due to the fact that overall economic patterns tend to be stable longer periods, with greater variability present during shorter timeframes. Additionally, any individual fleet may simply have a slow (or busy) day (or week) due to the success of their own business development efforts.

4. There are routes within New York State having significant empty/light truck movements.

This study reveals that certain routes tend to have a significant number of empty trucks plying them. Such routes are significantly empty/light for this sample of the population. The distinction being drawn here is that while some routes may have a low distribution of empty trucks, the sheer volume of trucks present on these roads indicate a large number of empty trucks are physically present.

5. Routes with significant empty truck movements vary by distribution of cargo types.

Of the cargo types studied, it was revealed that certain routes have a large number of empty trips specific to a given cargo type. The same route may not have a significant presence of empty trips concerning another cargo type. This trend may be an artifact of the particular make-up of the fleets in the sample studied and may change significantly as the sample size is increased.

6. Directionality plays a significant role concerning whether or not a route is significantly traveled by empty trucks.

Related to Conclusion 5, it was revealed that within any specific route, directionality plays a significant role. Understanding this directionality is very important, if meaningful follow up activity, such as trying to match loads with empty trips are attempted. In the previously mentioned example, attempting to match a load destined to the north of the load's origin would be less likely to be successful, than if the load were destined to the south.

RECOMMENDATIONS FOR FURTHER WORK

This study has determined that routes on which a significant number of empty/light trucks operate are present in New York State. It is suggested that several follow up efforts may reveal avenues for capitalizing on this unused capacity. Putting the fuel expended by the empty truck to work carrying a load will lead to less fuel being consumed overall and greater productivity for the state and nation.

Converting the empty truck trips to freight moving trips has profound value in the economy, the environment and the stability of the freight industry. The study team would like to suggest the following steps to expand the understanding of empty truck activity and the opportunities that it represents:

1. Expand the fleet sample.

The sample of fleets used in this study includes approximately two dozen fleets that are actively contributing fuel economy and route data to the HIVIS database. The number and variety of fleets in HIVIS is changing on a monthly basis and will likely double in the next six months. Periodically repeating the analysis with the increasing sample sizes that HIVIS offers will provide a measure of the eventual sample size that will be necessary to accurately represent the freight industry as a whole

2. Increase validation set.

This study has performed a first level testing on the load verification algorithm using and handful of trips from two fleets. Further verification and perhaps refinement of the algorithm should be performed by engaging more fleets in the testing process and including more trips per fleet.

3. Regular monitoring.

While the novel nature of the capability to summarize light/heavy truck activity has not yet allowed an assessment of the use of this information, uses in the fields of economic and transportation planning seem promising. Calmar suggests that a quarterly or annual summary of empty, or light, trip activity may reveal an additional dimension for consideration.